Inter (Part-I) 2017

Physics	Group-II	PAPER: I
Time: 2.40 Hours	(SUBJECTIVE TYPE)	Marks: 68

SECTION-I

2. Write short answers to any EIGHT (8) questions: (16)

(i) Why do we find it useful to have two units for amount of substance, the kilogram and the mole?

Ans

(a) Kilogram is useful when we measure a specific amount of mass without considering the number of atoms or molecules.

(b) Mole is useful when we want to consider fixed number of atoms or molecules.

(ii) Show that the famous Einstein equation $E = mc^2$ is dimensionally consistent.

Ans **Data:**

Given equation is $E = mc^2$

To Determine:

Equation is dimensionally consistent.

Since, $E = mc^2$

where c is velocity of light.

Dimensions of energy are that of work.

Therefore, dimensions of L.H.S. = $[E] = [ML^2T^{-2}]$

Dimensions of R.H.S. = $[mc^2] = [M(LT^{-1})^2] = [ML^2T^{-2}]$

Hence, Dimensions of LHS = dimensions of RHS

So, above equation is dimensionally correct.

(iii) Explain significant figures.

Ans Significant figures are the measured or calculated digits for a quantity, which are reasonably reliable.

(iv) Differentiate between precision and accuracy.

Ans The precision of a measurement is determined by the instrument or device being used while the accuracy of a measurement depends on the fractional or percentage uncertainty in that measurement.

(v) Define the term unit vector and position vector.

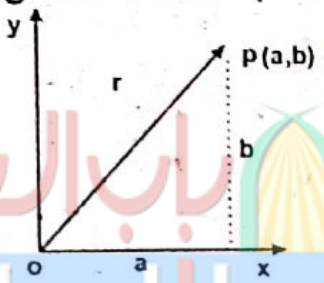
Ans **(a) Unit vector:**

"A vector whose magnitude is one is called unit vector." It is used to represent the direction of vector.

$$\hat{A} = \frac{\vec{A}}{|\vec{A}|}$$

(b) Position vector:

"A vector that describes the location of a point in space with respect to origin is called position vector."



(vi) Can you add zero to null vector? Explain.

Ans It is not possible to add zero to null vector because zero is a scalar quantity and null vector is a vector quantity. A scalar and vector cannot be added into one another. Because both have different natures.

(vii) State only two conditions of equilibrium.

Ans **1st condition:**

The vector sum of all forces acting on it must be zero.

Mathematically, $\Sigma F = 0$.

2nd condition:

For a body in equilibrium, the vector sum of all the torques acting on it about any arbitrary axis should be zero.

Mathematically, $\Sigma\tau = 0$.

(viii) Define impulse and show that how it is related to linear momentum.

Ans **Impulse:**

"The impulse provided by a force is the product of force and time for which it acts."

It equals to change in momentum of the object.

$$\text{Impulse} = \vec{F} \times t = m\vec{v}_f - m\vec{v}_i.$$

$$\text{Impulse} = I = \text{force} \times \text{time}$$

$$I = F \times \Delta t$$

As we know that

$\because$ $(F = ma)$

$$= ma \times \Delta t$$

$\because$ $$a = \frac{v_f - v_i}{t}$$

$$I = m\left(\frac{v_f - v_i}{t}\right) \times t$$

$$I = m(v_f - v_i)$$

$$I = mv_f - mv_i$$

$$I = \Delta P$$

(ix) Show that the range of projectile is maximum when projectile is thrown at an angle of 45° with the horizontal.

Ans As we know,

$$R_{max} = \frac{v_i^2}{g} \qquad \sin 2\theta = 1$$

$\because$ $$R = \frac{v_i^2}{g} \sin 2\theta$$

$$\sin 2\theta = 1$$

$$2\theta = \sin^{-1} 1$$

$$2\theta = 90^\circ$$

$$\theta = \frac{90}{2} = 45^\circ$$

(x) Derive expression of range and time of flight of projectile.

Ans **Time of Flight:**

This can be obtained by taking S = h = 0, because the body goes up and comes back to same level, thus, covering no vertical distance. If the body is projecting with velocity v making angle θ with a horizontal, then its vertical component will be $v_i \sin\theta$. Hence, the equation is:

$$S = v_i t + \frac{1}{2} gt^2$$

$$0 = v_i \sin\theta\, t - \frac{1}{2} gt^2$$

$$t = \frac{2v_i \sin\theta}{g} \qquad (1)$$

Range of the Projectile:

To determine the range R of the projectile, we multiply the horizontal component of the velocity of projection with total time taken by the body after leaving the point of projection. Thus,

$$R = v_{ix} \times t \quad \text{using eq. (1)}$$

$$R = \frac{v_i \cos\theta \times 2v_i \sin\theta}{g}$$

$$R = \frac{v_i^2}{g} 2 \sin\theta \cos\theta$$

But, $2 \sin\theta \cos\theta = \sin 2\theta$, thus, the range of the projectile depends upon the velocity of projection and the angle of projection.

Therefore; $$R = \frac{v_i^2}{g} \sin 2\theta \qquad (2)$$

For the range R to be maximum, the factor $\sin 2\theta$ should have maximum value which is 1 when $2\theta = 90^\circ$ or $\theta = 45^\circ$.

(xi) Define elastic and inelastic collisions.

Ans

Elastic collision	Inelastic collision
1. A collision in which both linear momentum and kinetic energy are conserved *i.e.*, remain constant, is called elastic collision.	1. A collision during which the total momentum is conserved but total K.E. before and after collision is not conserved (*i.e.*, does not remain constant) is called inelastic collision.
2. **Example:** When a hard ball is dropped on a marble floor from a certain height, it rebounds to very nearly the initial height. Thus, the ball loses negligible amount of energy in the collision with the floor.	2. **Example:** When two tennis balls collide, then they will rebound with velocities less than the velocities before collision. During collision, some K.E. is lost.

(xii) Explain what do you understand by the term viscosity.

Ans Viscosity measures, how much force is required to slide one layer of the liquid over another layer. Substances that do not flow easily, such as thick tar and honey, etc. have large coefficients of viscosity. Substances which flow easily, like water, have small coefficients of viscosity.

3. Write short answers to any EIGHT (8) questions: (16)

(i) Write some methods to obtain solar energy.

Ans

1. To obtain solar energy, much higher temperature can be achieved by concentrating solar radiation on to a

small surface area by using huge reflectors (mirrors) or lenses to produce steam for running a turbine.

2. The other method is the direct conversion of sunlight into electricity through the use of semi-conductor devices called solar cells, also known as photo voltaic cells.

(ii) An object has 1 J of potential energy. Explain what does it mean.

Ans An object having 1 J of potential energy means that the work done stored in the object in the form of potential energy has the capacity to do work of 1 J.

For example, if an object is lifted up by a force of one Newton through a height of one meter, the work done is stored in the object as potential energy of one Joule. If the object is allowed to fall vertically downward, it has the capacity to do 1 Joule work.

(iii) What does negative sign show in the expression $U_g = -\frac{GMm}{R}$.

Ans The negative sign shows in the expression $U_g = -\frac{GMm}{R}$ that the Earth's gravitational field for mass m is attractive.

(iv) What is moment of inertia? Explain its significance.

Ans **Moment of inertia:**

"It is defined as the product of mass of particle and square of its distance from axis of rotation."

It is denoted by I.

$$I = mr^2$$

Significance:

For a body in linear motion, the ratio of the force to acceleration is constant.

Mathematically, it is written as:

$$F/a = m \text{ (constant)} \qquad (1)$$

Similarly, for a body rotating about any axis, the ratio of the torque to the angular acceleration is constant

$$\tau = I\alpha$$

$$\frac{\tau}{\alpha} = I = \text{constant} \qquad (2)$$

By comparing (1) and (2), it can be seen that the moment of inertia of a rotating body is analogous to the mass of a body in linear motion.

(v) State the practical use of rotational K.E. by fly wheels.

Ans Rotational kinetic energy (K.E) is put to practical use by fly wheels, which are essential parts of many engines. A fly wheel stores energy between the power stokes of the pistons, so that the energy is distributed over the full revolution of the crankshaft and hence, the rotation remains smooth.

(vi) When mud flies off the tyre of moving bicycle, in what direction does it fly? Explain.

Ans The mud will fly off tangentially along a straight line. When the tyre rotates, a centripetal force acts on the mud which is equal to the adhesive force between the tyre and mud. When the angular speed of the tyre increases, the centripetal force on the mud also increases. When this centripetal force is greater than the adhesive force, the mud leaves the tyre and flies off tangentially along a straight line due to centrifugal force which is simply the reaction of the centripetal force.

(vii) How a particular station is tuned in radio?

Ans A radio can be tuned into a particular station frequency by adjusting the capacitance in an L-C circuit.

(viii) State the total energy of the vibrating mass and spring is constant.

Ans When the K.E. of the mass is maximum, the P.E. of the spring is zero. Conversely, when the P.E. of the spring is maximum, the K.E. of the mass is zero. Thus the total energy of the vibrating mass and spring is constant *i.e.*,

$$\text{Total Energy} = \text{P.E.} + \text{K.E.} = \frac{1}{2}kx_o^2$$

(ix) Does frequency depend on amplitude for harmonic oscillator?

Ans No, the frequency of oscillator is independent of the amplitude of oscillation.

The relation for frequency of harmonic oscillator are given as:

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$$

For Mass System:

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

These relations shows that frequency does not depend upon amplitude of harmonic oscillator.

(x) What do you observe in the collective effect of dots in the form of a picture?

Ans The collective effect of dots in the form of a picture is also a factor in the decrease or increase dynamic range of pixels. So, with the increased of dots, the image quality increases, in the form of a picture.

(xi) Why sound travels faster in hydrogen than in oxygen?

Ans Oxygen and hydrogen have nearly the same elastic properties, but the density of hydrogen is less than that of air. That's why, sound travels faster in hydrogen than in oxygen.

(xii) What features do longitudinal waves have in common with transverse waves?

Ans The following features are common in transverse waves and longitudinal waves:

- Both are mechanical waves.
- Both waves transfer energy from one point to another but not matter.
- Both produce disturbance in medium through which they travel.

- Both have frequency 'f' and wavelength 'λ" *i.e.*, v = fλ.

4. Write short answers to any SIX (6) questions: (12)

(i) How would you distinguish between un-polarized and plane-polarized lights?

Ans When light is passed through a polaroid, the emerging light beam has all the electric vectors confined in one plane at right angles to its direction of propagation. Such light is called plane polarized light (polaroid is named as polarizer). When another polaroid is placed in the path of polarized light with its axis parallel to the first polaroid, the total light will pass through the second polaroid. If second polaroid is rotated through 90°, no light passes through it, but ordinary or unpolarized light will totally pass through it in all directions. This second polaroid distinguishes the plane-polarized light from ordinary or unpolarized light. The polaroid used to test polarized light is called an analyzer.

(ii) Why diffraction grating cannot be used for X-rays diffraction?

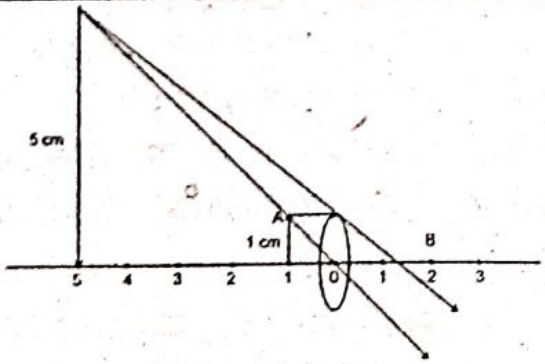
Ans X-rays is a type of electromagnetic radiation of much shorter wavelength, typically of the order of 10^{-10} m, therefore, diffraction grating cannot be used for X-rays diffraction.

(iii) If white light is incident on a film of irregular thickness at all possible angles, what will be the pattern of interference fringes? Explain your answer.

Ans There exist some points on the screen where crests meet troughs giving rise to destructive interference and dark fringes are thus formed.

(iv) A magnifying glass gives a five times enlarged image at a distance of 25 cm from the lens. What will be the focal length of the lens?

Ans We can give the answer of the above question through a graph by drawing a ray diagram.



From the above graph, we measure the distance 'OB' which is equal to focal length f. Its value is 6.2 cm, *i.e.*, f = 6.2 cm.

(v) What are three major components of fibre optic communication system?

Ans Three major components of fibre optic communication system are given below:

(a) Single-mode step index.
(b) Multi-mode step index.
(c) Multi-mode graded index.

(vi) Why does the pressure of a gas in a car tyre increase when it is driven through some distance?

Ans When a car is driven through some distance, work done by the car is partly spent in overcoming the frictional force between the road and the car tyre. Some part of work done against friction is converted into heat which raises the temperature of the gas in a car tyre. As we know that pressure is directly proportional to absolute temperature at constant volume, therefore, the pressure must increase because the heat energy increases the velocity and collisions of gas molecules. As a result, molecular collisions against the walls of a tyre increase the pressure of air inside the tyre.

(vii) A real heat engine is less efficient than carnot engine. Why?

Ans The efficiency of carnot engine depends on the temperature of hot and cold reservoir. No heat engine can

be more efficient than a carnot engine because of operating between the same two temperatures.

(viii) What is the similarity and difference between internal energy and gravitational P.E.?

Ans Similarity:

Internal energy is similar to gravitational P.E. So like the gravitational P.E. it is the internal energy and not its absolute value, which is important.

Difference:

The sum of all forms of molecular energies in a thermodynamic system is known as internal energy. While the potential energy due to gravitational field near the surface of the Earth at a height h is given by the formula, P.E. = mgh, is called gravitational potential energy.

(ix) State second law of thermodynamics in terms of entropy.

Ans According to this law;

"If a system undergoes a natural process, it will go in the direction that causes the entropy of the system plus the environment to increase."

SECTION-II

NOTE: Attempt any Three (3) questions.

Q.5.(a) What is projectile? Derive expressions for the:
(i) Height (ii) Horizontal range (5)

Ans Define:

Projectile motion is two dimensional motion under constant acceleration due to gravity.

(i) Height:

In order to determine the maximum height the projectile attains, we use the equation of motion

$$2aS = v_f^2 - v_i^2$$

As body moves upward, so $a = -g$, the initial vertical velocity $v_{iy} = v_i \sin\theta$ and $v_{fy} = 0$ because the body comes to rest after reaching the highest point. Since,

S = height = h

So, $-2gh = 0 - v_i^2 \sin^2 \theta$

or $$h = \frac{v_i^2 \sin^2 \theta}{2g}$$

(ii) Horizontal range:

Maximum distance which a projectile covers in the horizontal direction is called the range of the projectile.

To determine the range R of the projectile, we multiply the horizontal component of the velocity of projection with total time taken by the body after leaving the point of projection. Thus,

$$R = v_{ix} \times t \qquad \text{using eq. (1)}$$

$$R = \frac{v_i \cos\theta \times 2v_i \sin\theta}{g}$$

$$R = \frac{v_i^2}{g} 2 \sin\theta \cos\theta$$

But, $2 \sin\theta \cos\theta = \sin 2\theta$, thus, the range of the projectile depends upon the velocity of projection and the angle of projection.

Therefore, $$R = \frac{v_i^2}{g} \sin 2\theta \qquad (2)$$

For the range R to be maximum, the factor $\sin 2\theta$ should have maximum value which is 1 when $2\theta = 90°$ or $\theta = 45°$.

(b) The magnitude of dot and cross product of two vectors are $6\sqrt{3}$ and 6, respectively. Find the angle between vectors. (3)

Ans $A.B = 6\sqrt{3}$

$A \times B = 6$

Find $\theta = ?$

$A.B = AB \cos\theta$ (1)

$A \times B = AB \sin\theta$ (2)

Dividing eq. (2) by (1),

$$\frac{A \times B}{A.B} = \frac{AB \sin 0}{AB \cos 0}$$

$$\frac{6}{6\sqrt{3}} = \tan 0$$

$$\frac{1}{\sqrt{3}} = \tan 0$$

$$\tan 0 = 0.57$$

$$0 = \tan^{-1} 0.57$$

$$0 = 30^{\circ}$$

Q.6.(a) Define gravitational field. Prove that work in the earth's gravitational field is independent of the path followed. (5)

Ans **Gravitational field:**

"The space around earth in which its gravitational force acts on body is called gravitational field."

Gravitational force:

"The force acting in gravitational field is called as gravitational force."

Work done:

The work done in gravitational field is independent of path followed. Consider an object of mass 'm' which is displaced with constant velocity from point A to B along three paths in presence of gravitational force. We calculate work done along three paths in following.

Path I:

The work done by gravitational force along path ABD can split into two paths:

$$W_{ADB} = W_{AD} + W_{DB}$$

Here,

$$W_{AD} = \vec{F} \cdot \vec{d}$$
$$= Fd\cos\theta$$
$$= mgh \cos 180^\circ$$
$$= mgh\,(-1)$$
$$= -mgh$$

$$W_{BD} = \vec{F} \cdot \vec{d}$$
$$W_{BD} = Fd \cos\theta$$
$$W_{BD} = Fd \cos 90^\circ$$
$$W_{BD} = 0$$

So,

$$W_{ADB} = 0 + (-mgh)$$
$$= -mgh \qquad (1)$$

Path II:

The work done along path ACB can be divided into second path:

$$W_{ACB} = W_{AC} + W_{BC}$$

here,

$$W_{AC} = \vec{F} \cdot \vec{d}$$
$$= Fd\cos\theta$$
$$= mgh \cos 180^\circ$$
$$= mgh\,(-1)$$
$$= -mgh$$

Again,

$$W_{BC} = \vec{F} \cdot \vec{d}$$
$$= Fd\cos\theta$$
$$= mg\,d \cos 90^\circ$$
$$= mgh\,(0)$$
$$= 0$$

So, $W_{ACB} = -mgh + 0$

$$W_{ACB} = -mgh \qquad (2)$$

Path III:

It is curved path. We divide this path into a series of horizontal and vertical steps. There is no work done along horizontal steps because 'mg' is perpendicular to the displacement for these steps. The work is done by force of gravity along the vertical displacement (Δy_1, Δy_2, Δy_n)

$$W_{AB} = \vec{F}.\Delta y_1 + \vec{F}.\Delta y_2 + ------ \vec{F}.\Delta y_n$$
$$= F\Delta y_1 \cos\theta + F\Delta y_2 \cos\theta ----- F\Delta y_n \cos\theta$$

Here $F = mg$ and $\theta = 180°$

$$W_{AB} = mg\,\Delta y_1 \cos 180° + mg\Delta y_2 \cos 180° ---- F\Delta y_n \cos\theta$$
$$= mg\Delta y_1 (-1) + mg\Delta y_2(-1) ----- mg\Delta y_n(-1)$$
$$= -mg\,(\Delta y_1 + \Delta y_2 ----- \Delta y_n)$$
$$= -mg\,(h)$$
$$= -mgh \qquad (3)$$

Conclusion:

From eq. (1), (2), (3), it is concluded that work done in earth's gravitational field is independent of path followed.

(b) A body of moment of inertia 0.80 kgm² about a fixed axis, rotates with a constant angular velocity of 100 rad s⁻¹. Calculate its angular momentum and torque to sustain its motion. (3)

Ans **Data:**

$I = 0.80$ kgm²

$\omega = 100$ rad s^{-1}

i) $L = ?$

ii) $\tau = ?$

Solution:

i) $L = I\,\omega$

$= 0.80 \times 100$

$= 80$ Js

ii) As $\tau = I\,\alpha$

Since, angular velocity is constant, so, angular acceleration will be zero *i.e.*, $\alpha = 0$

$$\tau = (I)(0)$$
$$\tau = 0$$

Q.7.(a) Define Stoke's law and show that the terminal velocity is directly proportional to square of radius of the object. (5)

Ans **Stoke's Law:**

"An object moving through a fluid experiences a retarding force called a drag force. The drag force increases as the speed of the object increases."

The drag force F on a sphere of radius r moving slowly with speed v through a fluid of viscosity η is given by Stokes' law as under:

$$F = 6 \pi \eta r v$$

Terminal Velocity:

Consider a water droplet such as that of fog falling vertically, the air drag on the water droplet increases with speed. The droplet accelerates rapidly under the over-powering force of gravity which pulls the droplet downward. However, the upward drag force on it increases as the speed of the droplet increases.

To find the terminal velocity v_t in this case, we use Stoke's Law for the drag force. Equating it to the weight of the drop, we have

$$mg = 6 \pi \eta r v_t$$

or $$v_t = \frac{mg}{6 \pi \eta r}$$

The mass of the droplet is ρV,

where volume $V = \frac{4}{3} (\pi r^3)$

Substituting this value in the above equation, we get:

$$v_t = \frac{2g r^2 \rho}{9 \eta}$$

As $\frac{2g\rho}{9\eta}$ is constant

So, $v_t \propto r^2$

Terminal velocity is directly proportional to square of radius of the object.

(b) 336 J of energy is required to melt 1 g of ice at 0°C. What is the change in entropy of 30 gm of water at 0°C as it is changed to ice at 0°C by a refrigerator? (3)

Ans Given data:

$H_f = 336\ Jg^{-1}$

$m = 30\ g$

$T = 0°C = 0°C + 273 = 273\ K$

Find: $\Delta S = ?$

Formula:

$$\Delta S = \frac{\Delta Q}{T} \qquad \text{(i)}$$

$$\Delta Q = mH_f = 30 \times 336\ J$$

Put in equation (i),

$$\Delta S = \frac{-30 \times 336}{273} = \frac{-10080}{273}$$

$$\boxed{\Delta S = -36.92\ JK^{-1}}$$

Q.8.(a) What is simple pendulum? Show that its motion is simple harmonic motion. Derive an expression for its time period. (5)

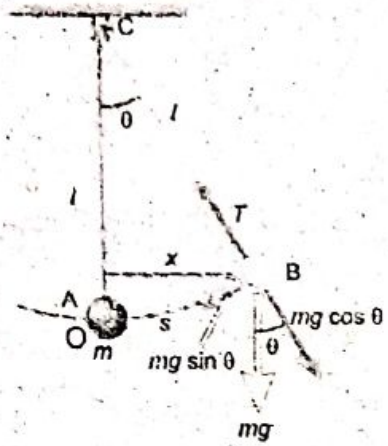
Ans Simple Pendulum:

A simple pendulum consists of a small heavy mass *m* suspended by a light string of length *l* fixed at its upper end, as shown in the following Fig. When such a pendulum is displaced from its mean position through a small angle θ to the position B and released, it starts oscillating to and fro over the same path. The weight mg of the mass can be resolved into two components; mg sin θ

along the tangent at B and mg cos θ along CB to balance the tension of the string. The restoring force at B will be:

$$F = -mg \sin \theta$$

When θ is small, $\sin \theta \approx \theta$



So, $F = m\,a = -m\,g\,\theta$ (1)

or $a = -g\,\theta$

But $\theta = \dfrac{\text{Arc AB}}{l}$

When θ is small Arc AB = OB = x, hence $\theta = \dfrac{x}{l}$

Thus, $a = -\dfrac{gx}{l}$ (2)

At a particular place, 'g' is constant and for a given pendulum, 'l' is also a constant.

Therefore, $\dfrac{g}{l} = k$ (a constant)

and the motion of the simple pendulum is simple harmonic. Comparing eq. (2) with $a = -\omega^2 x$

$$\omega = \sqrt{\frac{g}{l}}$$

As time period $T = \dfrac{2\pi}{\omega}$

Hence, $T = 2\pi\sqrt{\dfrac{l}{g}}$ (3)

This shows that the time period depends only on the length of the pendulum and the acceleration due to gravity. It is independent of mass.

(b) A pipe has a length of 1 m. Determine the frequencies of fundamental and the first two harmonics: (i) if pipe is open at both ends, (ii) if pipe is closed at one end. (3)

Ans

(i)

$$f_1 = \frac{nv}{2l} = \frac{1 \times 340\ ms^{-1}}{2 \times 1\ m} = 170\ s^{-1} = 170\ Hz$$

$$f_2 = 2 f_1 = 2 \times 170\ Hz = 340\ Hz$$

and $$f_3 = 3 f_1 = 3 \times 170\ Hz = 510\ Hz$$

(ii)

$$f_1 = \frac{nv}{4l} = \frac{1 \times 340\ ms^{-1}}{4 \times 1\ m} = 85\ s^{-1} = 85\ Hz$$

In this case only odd harmonics are present, so

$$f_3 = 3 f_1 = 3 \times 85\ Hz = 255\ Hz$$

and $$f_5 = 5 f_1 = 5 \times 85\ Hz = 425\ Hz$$

Q.9.(a) What is interference of light waves? Describe Young's double slit experiment. (5)

Ans **Young's Double Slit Experiment:**

Figure shows the experimental arrangement, similar to that devised by Young in 1801, for studying interference effects of light. A screen having two narrow slits is illuminated by a beam of monochromatic light. The portion of the wavefront incident on the slits behaves as a source of secondary wavelets (Huygen's principle). The secondary wavelets leaving the slits are coherent. Superposition of these wavelets result in a series of bright and dark bands (fringes) which are observed on a second screen placed at some distance parallel to the first screen.

Let us now consider the formation of bright and dark bands. As pointed out earlier, the two slits behave as coherent sources of secondary wavelets. The wavelets arrive at the screen in such a way that at some points crests fall on crests and troughs on troughs resulting in constructive interference and bright fringes are formed. There are some points on the screen where crests meet troughs giving rise to destructive interference and dark fringes are thus formed.

(b) An astronomical telescope having magnifying power of 5 consists of two thin lenses 24 cm apart. Find the focal lengths of the lenses. (3)

Ans

Magnifying power $M = 5$

Distance between lenses $L = 24$ cm

Focal length of objective $f_o = ?$

We know that

$$L = f_o + f_e$$

$$24 = f_o + f_e \quad \text{(i)}$$

$$M = \frac{f_o}{f_e}$$

$$5 = \frac{f_o}{f_e}$$

$$F_o = 5 f_e$$

Putting in (i),

$$24 = 5 f_e + f_e$$

$$6 f_e = 24$$

$$f_e = \frac{24}{6}$$

$$\boxed{f_e = 4 \text{ cm}}$$

$$f_o = 5 f_e$$

$$f_o = 5(4)$$

$$\boxed{f_o = 20 \text{ cm}}$$